pole, the maximum number of disturbances occurring in spot latitudes and immediately higher. Equatorial prominences were not infrequent.

The data for the last four years, as deduced at South Kensington, are as follows :—

	1905.	1906.	1907.	1908.
North hemisphere . . .	3·4	3·9	3·5	2·5
South hemisphere . . .	3·0	2·6	3·9	3·1
Total daily frequency	6·4	6·5	7·4	5·6

The fewness of the number of days on which it has been possible to obtain good prominence records makes the above figures merely suggestive, and not final.

The poor observing weather of 1908, combined with the unfavourable situation at South Kensington, has very effectively militated against a fuller record.

In previous reports I have been able to include observations made during the first six months of the year by A. Riccò, but up to the present these are not available. W. J. S. L.

Solar Research.

Sun-spot Spectra.—The first portion of a "preliminary catalogue of lines affected in sun-spots," based upon photographs taken at Mount Wilson, and covering the region λ4000 to λ4500, has been published by Adams (*Ap. J.*, xxvii. 45). The behaviour of nearly nine hundred lines is indicated.

Following Fowler's identification of the banded spectrum of magnesium hydride in spots, Olmsted, of the Mount Wilson laboratory, has found that an arc burning between poles of metallic calcium in an atmosphere of hydrogen gives a number of bands, the two most prominent of which account for the well-known spot bands in the red near 6382 and 6389. From experimental evidence, it is considered probable that the bands in question are produced by some compound of calcium and hydrogen (*Ap. J.*, xxvii. 66).

Father Cortie has drawn attention to the apparent strengthening in sun-spots of many lines which are attributed to water vapour, which has led him to suggest the possible existence of water vapour, in the form of superheated steam, over sun-spots (*Ap. J.*, xxviii. 379).

The Mount Wilson equipment for the investigation of sun-spot spectra has been extended by the erection of a vertical telescope of 60 feet focal length combined with a spectrograph of 30 feet focal length. The cœlostat and objective are placed at the summit of a skeleton steel tower about 60 feet high, while the spectrograph, which is of the autocollimating type, occupies a circular well 8½ feet in diameter and 30 feet deep. The reduced atmospheric

disturbance of the primary image, and the constancy of temperature of the spectrograph, have contributed to very successful photographs of the spot spectrum (*Ap. J.*, xxvii. 204). Professor Hale is arranging for the erection of a similar instrument with a spectrograph of 75 feet focal length, to work in conjunction with an object-glass of 150 feet focal length (*Ap. J.*, xxviii. 343).

In consequence of the demand for increased electrical power created by the sun-spot work on Mount Wilson, an additional laboratory has been equipped in Pasadena. Profiting by experience with the new Tower Telescope, Professor Hale has here erected a 30-feet autocollimating spectrograph in a well of corresponding depth below the floor of the laboratory, and has conveniently arranged the electric furnace and other light sources about the slit as centre (*Ap. J.*, xxviii. 244).

The first results from the new laboratory refer to the electric-furnace spectra of titanium and vanadium, which have been investigated by Dr. King. A furnace of the "tube resistance" type was employed, and temperatures ranging up to 3000° C. were attained. Under these conditions, 85 per cent. of the arc lines were present in the case of titanium, and 73 per cent. in the case of vanadium; but the relative intensities were different from those of the arc spectrum, enhanced (spark) lines being notably weakened. Dr. King concludes that since electrical action other than ionisation at a heated surface was entirely excluded, and possible chemical action was reduced to a minimum, "there is nothing to indicate that temperature was not the sole and sufficient agent in producing these spectra" (*Ap. J.*, xxviii. 300). Professor Hale is of opinion that these investigations leave little doubt as to the correctness of the view that the changed intensities of the metallic lines in spots are due to a reduction of temperature in the spot vapours (*Ap. J.*, xxviii. 319).

The spectrum of scandium has been investigated by Fowler. It is found that the enhanced lines are much more prominent in the solar spectrum than the other lines, and that, while the former are weakened in spot spectra, the latter are very considerably strengthened (*Phil. Trans.*, vol. ccix*a*. p. 47).

In a paper read at the meeting of the British Association, Professor Whittaker criticises the evidence which has been brought forward in support of the view that the sun-spot spectrum directly indicates a relatively low temperature. Attention is drawn to the fact that the mere existence of bands due to compounds is inconclusive, since compounds may be formed by increase of pressure as well as by reduction of temperature. It is also suggested that the variations in the intensities of the metallic lines might be produced by high pressure in the spots (*Observatory*, xxxi. 372). On the other hand, Mr. Evershed states that a series of measures made by him of certain iron lines which are subject to large pressure shifts prove that in the spots examined the pressure could not have differed by more than a quarter of an atmosphere from that over the adjacent photosphere (*Observatory*, xxxi. 463).

An observation which bears upon the significance of enhanced (spark) lines in sun-spots and other celestial light sources has been recorded by Hemsalech and De Watteville. It is stated that some of the enhanced lines of iron in the ultra-violet are among the lines given by the inner cone of a Bunsen flame fed with air carrying fine particles generated by an enclosed arc or spark. These lines are not seen in the presumably hotter oxyhydrogen flame (*Comptes Rendus*, June 29).

The supposed "reversals" of lines in sun-spot spectra first described by Young, and afterwards by Mitchell, have received a new interpretation. These lines have been successfully registered by the 30-feet spectrograph at Mount Wilson, and the possible existence of a magnetic field in spots having been suggested by the discovery of vortices about spots in spectro-heliographic work on the Hα line, the polarisation phenomena were carefully investigated. In accordance with experiments on the Zeeman effect, it was found that in the case of spots near the centre of the disc, one or other component of the really double lines could be extinguished by suitable adjustment of a Fresnel rhomb and Nicol prism in front of the slit. The two components are thus circularly polarised in opposite directions, and it is deduced that the rapidly moving particles which produce the field are negatively charged.

When the rhomb and Nicol are adjusted to extinguish one of the components in the case of a spot associated with a vortex moving in a particular direction, the other component is extinguished if another spot in which the vortex motion is oppositely directed be brought on the slit, the apparatus being otherwise as at first. In the case of a spot near the limb, the field is nearly at right angles to the line of sight, and the doublets observed away from the limb are replaced by triplets in accordance with theory and experiment. From the measured separation of the doublets, Professor Hale estimates the strength of the magnetic field as about 1000 Gauss units; and as there is evidence that it rapidly diminishes in passing outwards, he considers it very improbable that terrestrial magnetic disturbances are caused by the direct effect of the magnetic field in spots (*Ap. J.*, xxviii. 315). Dr. Schuster has also concluded that "the magnetic disturbances hitherto associated with the state of the sun's surface cannot be accounted for by the direct magnetic action of Professor Hale's solar vortices" (*Nature*, lxxix. 280).

Helium Absorption near Spots.—Photographs showing a dark line, apparently corresponding to D_3, in the neighbourhood of sun-spots, have been obtained by Mr. Nagaraja at Kodaikánal. These have been discussed by Father Cortie, Mr. Buss, Captain Daunt, and Mr. Evershed, and much valuable information has been given as to the conditions of visibility of the line (*Observatory*, xxxi. 51, 94, 133, 250, 353). Details of observations of this line during 1907 have been published by Captain Daunt (*M.N.*, lxviii. 620).

The Sun's Rotation.—The results of a further investigation of

the position of the sun's axis of rotation, as deduced from the records of spots for the period 1874–85, have been given by Professor Turner. It is suggested that the axis may possibly be describing a cone in space in a period which is nearly a year (*Papers of the I.U.S.R. Computing Bureau*, No. II.; *M.N.*, lxvii. 609.)

An important spectroscopic investigation of the sun's rotation as determined from displacements of the hydrogen lines has been made by Adams, from photographs taken at Mount Wilson. It is concluded, first, that the rotational velocity of the hydrogen gas is decidedly higher than that of the general reversing layer, amounting at the equator to 1° in the daily angular motion, and that the effective level of the absorbing gas lies very high in the Sun's atmosphere. The second conclusion drawn from the observations is that at the level of the hydrogen gas there is no equatorial acceleration similar to that indicated by low-level vapours and by the movements of sun-spots (*Ap. J.*, xxvii. 213).

A companion investigation has been made by Professor Hale on the rotation of the sun as determined from the motions of the hydrogen flocculi. The results agree with those of Adams in showing that the hydrogen in the sun does not show the equatorial acceleration observed in the case of sun-spots, faculæ, calcium flocculi, and reversing layer. As in the case of dark calcium flocculi to which attention was drawn by Mr Michie Smith, Professor Hale is of opinion that some of the dark hydrogen flocculi are also prominences photographed in projection on the Sun's disc (*Ap. J.*, xxvii. 219).

Mr. Fox, of the Yerkes Observatory, finds that only a small percentage of the prominences shown on the Sun's limb can be clearly followed on the disc as dark calcium flocculi. A preliminary attempt to determine the sun's rotation from these appearances indicates that the motion agrees closely with the motion of the hydrogen flocculi (*Ap. J.*, xxviii. 117).

The Spectroheliograph.—In addition to the work already mentioned, Professor Hale has obtained photographs on the Hα line which give unmistakable evidence of the existence of vortices about sun-spots. In one series of photographs a large hydrogen flocculus is depicted in course of being drawn into a spot, and Professor Hale is led to conclude that "sun-spots are centres of attraction, drawing toward them the hydrogen of the solar atmosphere." Reference has already been made to the magnetic field in spots to which the vortices are believed to give rise (*Ap. J.*, xxviii. 100).

Mr. Fox has given careful attention to the specially bright points in the calcium flocculi which occur in the neighbourhood of spots, and has concluded that they are the bases of eruptive prominences. Their spectra sometimes show many metallic lines and other appearances similar to those observed in prominences, and when traced to the limb prominences are seen to overhang the

(eruptive) flocculi. It should thus be possible to determine the distribution of eruptive prominences on the sun's disc (*Ap. J.*, xxviii. 258).

Spectroheliograms in the calcium line K_3 (the central dark reversal) have been obtained by Deslandres. Some of the long dark filaments shown on the photographs persist in the same positions for several rotations, and it is suggested that spots and filaments are manifestations of different parts of the same cyclonic motion (*Comptes Rendus*, November 30, 1016).

The development of a prominence which appeared on February 18, as illustrated by a series of twenty photographs taken at Kodaikánal, has been described by Evershed. The most striking feature was the accelerating velocity with which the entire mass left the sun (*Ap. J.*, xxviii. 79).

Structure of the Photosphere.—A study of the granulation of the photospheric surface has been made at Zô-sè by Chevalier. The granules found in a given photograph were quite unrecognisable in one taken ten minutes later, but on plates taken at intervals of a minute or half a minute they were substantially the same, though showing changes of shape, brightness, and relative positions. The displacements observed in comparing successive plates range from zero to thirty or more kilometres per second, and are widely different in direction. It is suggested that these displacements do not represent horizontal motion, but may correspond to undulatory movements more or less similar to those seen in a choppy sea (*Ap. J.*, xxvii. 12).

Further investigations of the movements of the solar granules made by the late Alexis Hansky have also been published. It is concluded that sun-spots have an oscillatory movement relative to the whole surface, the maximum velocity being 400 metres per second, and that the photospheric granules have non-periodic movements of short duration, with velocities of about 4 kilometres per second (*Mitt. Hauptsternwarte zu Pulkowo*, iii., No. 25; *Observatory* xxxi. 469).

The Solar Constant and Temperature of the Sun.—From measures of the sun's radiation made with the Ångström pyrheliometer, Dr. Scheiner deduces the value 2·22–2·29 calories for the solar constant. "The effective temperature" of the sun resulting from the observations is 6196° to 6252°, and it is estimated that the average real temperature of the photosphere is 7065° (*Pub. Ast. Obs. zu Potsdam*, No. 55; abstract in *M.N.*, lxviii. 662).

From a discussion of Langley's observations, Dr Goldhammer has estimated the actual temperature of the sun as 10,000° (*Ann. der Physik.*, xxv. 905), while Dr. O. Lummer considers it to be in the neighbourhood of 7000° (*Bull. Phil. Soc. Washington*, xv. 75).

An extended account of work on the solar constant has been given by Abbot and Fowle in vol. ii. of the *Annals of the Astrophysical Observatory of the Smithsonian Institution* (Washington,

1908). Details and discussion of comparable observations extending over several years are given; they are believed to indicate that the sun's radiation changes in intensity from time to time, and that these alterations are sufficient to appreciably affect the temperature of the earth.

Miscellaneous.—Professor R. W. Wood has pointed out that the presence of radially polarised light in the solar corona does not necessarily indicate the scattering of sunlight by small particles. He has found that the fluorescent light emitted by comparatively cool metallic vapours is strongly polarised, even when the exciting light is unpolarised. With mixed vapours the integrated complex fluorescence spectra would appear practically continuous, as is the case with the corona. Professor Wood considers it possible that the green line and other lines observed in the coronal spectrum may be the fluorescent lines of well-known substances (*Ap. J.*, xxviii. 75).

Dr. Schuster points out that the renewed sun-spot activity in August was possibly connected with the 4·79-year period, which he has previously shown to have persisted since sun-spots were first systematically observed (*Nature*, lxxix. 7).

An account of some anomalous forms of the K line of calcium in prominences, with numerous illustrations, has been published by Belopolsky (*Mitt. Hauptsternwarte zu Pulkowo*, ii., No. 24).

From a discussion of photographs of the corona of 1905, the late Alexis Hansky considered it probable that the forms and directions of the streamers depended upon the prominences over which they appeared. Some streamers seemed to emanate from points near to, but not coincident with, spots (*Mitt. Hauptsternwarte zu Pulkowo*, ii., No. 19).

The second volume of the *Transactions* of the International Union for Solar Research has been issued (University Press, Manchester). A full account of the proceedings at the Meudon Conference of 1907 is given, together with reports of committees and a few original papers. Definitive values of the new wave-lengths of standard iron lines are given by Fabry and Buisson (also in *Ap. J.*, xxviii. 169). A. F.

Double Stars.

The abbreviations used are—

M.N. : *Monthly Notices.*
A.N. : *Astronomische Nachrichten.*
L.O.B. : *Lick Observatory Bulletin.*
B.A.A. : *Journal of the British Astronomical Association.*

The number of measures published during the year is about the average:—E. D. Roe (6½-inch Clark), Syracuse, N.Y., gives a first contribution in *A.N.* 4259 of 47 pairs, ranging from 1″·0 to 53″·0 separation.

Professor Burnham (40-inch Clark), Yerkes, in *A.N.* 4261, has